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Sebeya Catchment Inventory in Rwanda

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ABSTRACT

BACKGROUND: Currently, there is a concern about soil erosion and flood management issues in Rwanda. This concern leads to the catchment development plans in the country including the Sebeya catchment. One of the important elements for easy implementation of a catchment management plan is to have an inventory that provides sufficient documentation on its characteristics, main features, and trends. **MATERIAL AND METHODS:** In developing this inventory, field surveys accompanied by questionnaire design and interview, internet research, relevant articles, and public reports were used to get relevant information. GIS software has been used to delineate and generate some important maps for the catchment. **RESULTS:** Existing data revealed that water quality and other significant pressing issues such as soil erosion accompanied by river sedimentation and floods were usually happening in this catchment. **CONCLUSIONS:** This research finds its necessity in making available detailed information for stakeholders trying to tackle any soil and water conservation project in the Sebeya catchment.

1. INTRODUCTION

Nowadays, soil erosion is one of the most serious environmental issues to which the planet is mostly facing. In most of Sub-Saharan Africa, more than 50% of the population heavily relies on local agriculture for food (1), where poor land management usually leads to extreme soil erosion. In Rwanda, extreme soil erosion is accelerated by abundant rainfall and agricultural expansion on steep slope terrain (2). Consequently, the country is committed to soil erosion and floods management plans in the Rwandan catchments.

Sebeya is a rural catchment located in the high elevation region of the country with altitude varying between 1,462 m to 2,979 m a.b.s.l.This catchment is also characterized by steep slopes and abundant rainfall varying between 1,200 to 1,700 mm per year (3). It is therefore imperative to plan for soil erosion and floods management in this catchment. Soil and water conservation projects have to be based on concrete information about the main features and natural hazards reported in the catchment.

This research intends to develop an inventory of Sebeya Catchment in Rwanda to provide useful information about slope, rainfall, soil, land use/land cover, and water resources.

The objectives of this study were:1) To delineate the catchment; 2) To locate all main features; 3) To make an inventory of land cover and land use; 4) To investigate socio-economic issues of farmers and 5) To investigate causes and factors affecting soil erosion in Sebeya catchment.

In developing this inventory, field surveys, internet research, relevant journal articles, and existing reports were used to get relevant information. Digital Elevation Model (DEM) has been used to delineate the catchment and generate some insightful maps for the catchment.

A catchment inventory can help in identifying potential concerns within the watershed on how various land uses can affect water quality. It guides the state and government agencies on how they are involved in the current and future planning of their catchment. With this inventory, it is easy and effective to plan for mitigating soil erosion and other natural hazards that are used to happen in the Sebeya catchment.

2. METHODOLOGY

2.1 Study area

2.1.1 Site localization

This study is entirely focused on Sebeya level 2 catchment which is a part of the larger level 1 Lake Kivu catchment and located in the Western province of Rwanda as presented in figure1. The main river flowing in this catchment is Sebeya, which originates in the mountains of Rutsiro District. It flows past the mission of Nyundo established in 1901 on the banks of the river about 12 kilometers upstream from Lake Kivu. The catchment is shared by four administrative units namely Rubavu and Nyabihu Districts in the North, and Rutsiro and Ngororero Districts in the South.

Located also on the Western flanks of the Congo-Nile divide, Sebeya and Lake Kivu catchments are some of the most upstream parts of the Congo River Basin (that flows into the Atlantic Ocean). Sebeya catchment is one of the small catchments that drain the western slopes of the Nile Congo watershed of Rwanda between 01°50'57.15" and 01°42'21.99" degrees South (22.984 km) latitude and 29°23'52.04" and 29°25' 06.14" degrees East (27.455 km) longitude (4). The total surface area of Sebeya catchment represents 1.38 % of the total surface area of Rwanda (26,338 km² including water bodies), which totalizes 364.2 km² (3).

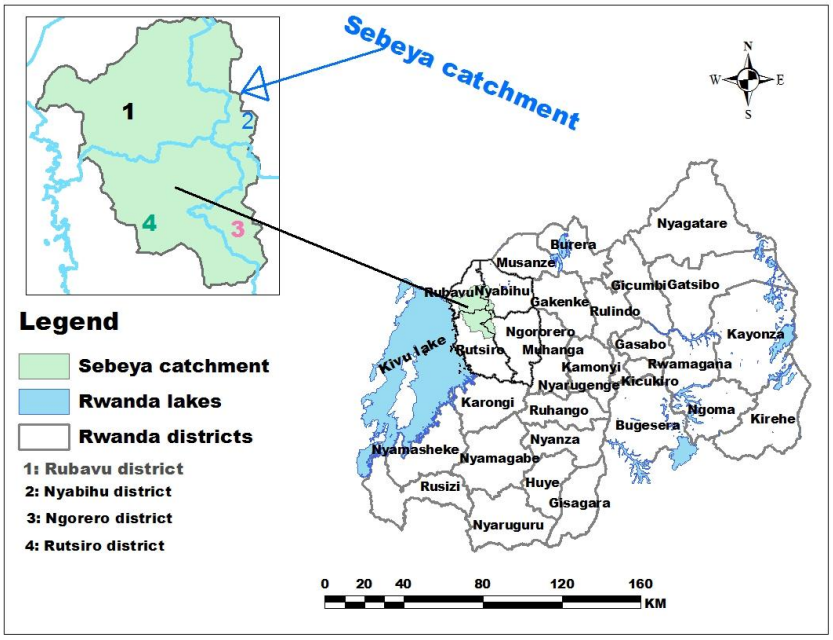

Figure No. 1: Sebeya catchment location map

2.1.2 Overlap between Districts and Sebeya catchment

Figure no.1 shows that Sebeya catchment extends on many sectors of 4 Districts while the table1 shows that the overlapped area between Rubavu and Sebeya catchment is the largest and equal to 44.6%. The next largest overlapped area comes to be 41.3% between Rutsiro and Sebeya catchment.

Table No. 1: The overlap between Districts and Sebeya catchment (5).

Districts			**The overlap between District and Catchment**		
District name	**Area in km²**	**Population**	**The overlapped area in km²**	**% of Catchment**	**Overlapped population**
Ngororero	679	403,662	37	11%	156,054
Rutsiro	1,157	294,740	139	41.3%	21,053
Nyabihu	532	324,654	38	11.3%	39,003
Rubavu	388	333,713	150	44.6%	18,185
Total			**363**	**100%**	**234,295**

2.1.3 Population density

The average density of Sebeya catchment from table1 is estimated to be 644 hab/km^2 which is bigger than the average population density of Rwanda (415habitants per km^2) (6).

The Northern part of Sebeya catchment in Rubavu District (Nyakiliba Rugerero, and Gisenyi sectors) is occupied by a significant urban population, which is equal to a quarter of the population. The sectors along the shores of Lake Kivu and the main road from Rubavu to Musanze are still very highly populous with more than 1000 hab/km² while the sectors in the highlands of the South-East show the lowest population density fluctuating from 250 to 500 hab/km² (4).

The population in Sebeya catchment is young with about 55 % of the population below 20 years. The total female population surpasses the male population by about 9%. The population is predominantly rural (74%). The population living in villages is 44% in concentrated housing and 30% in dispersed housing. The high population in

Sebeyacatchment influences the landscape by increasing pressure on land for agriculture, glass land for cattle, and residential houses.

The increase in population also results in new developments, urbanization, and increased impervious area throughout the catchment.

2.1.4 Soil characteristics

Butare complex (Bu) and the volcanic rocks of Virunga Mountains (B) are two main geological formations in Sebeya catchment and nitosol, acricol, alisol, and lixisol are the main soil classes(IWRM, 2018). The soil in this catchment favors agriculture due to its high infiltration rates and its high mineral content except for the case of clay soils on flat topography encountered in the catchment. The combination of the geological formation and soil data characterize the Sebeya catchment as a fragile ecosystem susceptible to heavy erosion (7). The soil map provided (figure2) highlights the soil types in the Sebeya catchment.

The mineral components of soil, sand, silt, and clay determine the soil texture which affects soil behavior, in particular its retention capacity for nutrients and water.

The clumping of the soil textural components of sand, silt, and clay forms aggregates, and the further association of those aggregates into larger units forms soil structures. The soil structure affects aeration, water movement, conduction of heat, plant root growth, and resistance to erosion. Water has the strongest effect on soil structure due to its solution and precipitation of minerals.

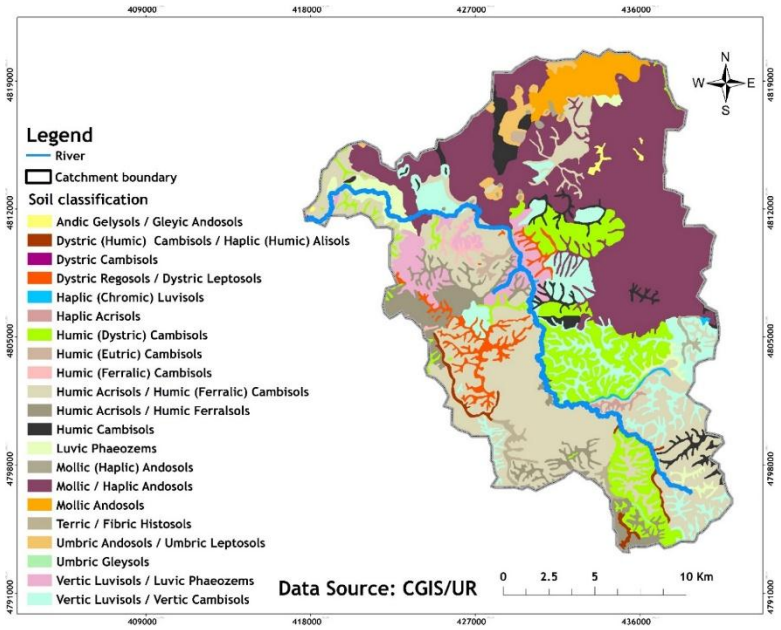

Figure No. 2: Soil map of Sebeya catchment

2.1.5 Site topography

- **Landscape**

The topography of Sebeya catchment is among the mountainous chain of Congo-Nile river divide extending North-South from Nyungwe forest in South to Gishwati forest in North. This mountainous chain divides the country into two watersheds. The catchment is characterized by steep slopes and complex topography (abrupt changes of altitude on small distances).

- **Topographic map and main features of the site**

Using ArcGIS, the topographic map (figure no.3) was produced. Apart from water treatment and hydropower plants visited, the main features highlighted in Sebeya catchment include roads, schools, Gisenyi metro station, Gishwati forest, health centers, and local authorities' offices.

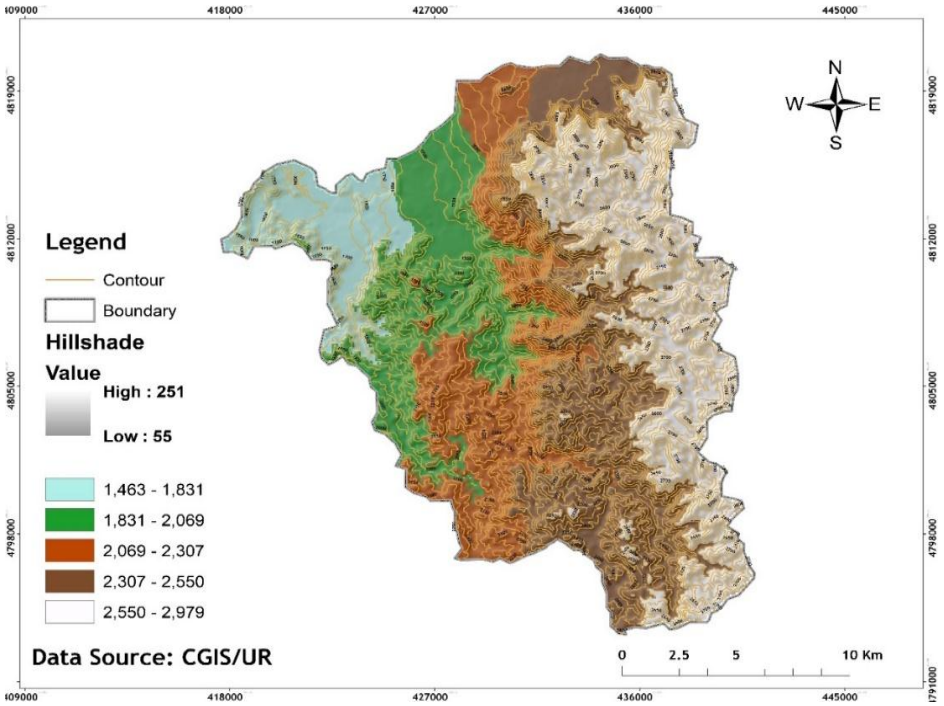

Figure No. 3: Topographic map of Sebeya catchment

- **Slope Classes**

In 2018, the Ministry of Environment (MoE) of Rwanda has grouped the slope into five classes according to the risk level of erosion as shown in the table 2.

Table No. 2: Slope classes and their risk level of erosion

S/N	Slope %	The risk level of erosion
1	0-6	Very low
2	6-16	Low
3	16-40	Medium
4	40-60	High
5	> 60	Very high

A slope map showing slope classes in the Sebeya catchment was developed (figure4). It reveals that a great part of this catchment falls in medium risk to very high risk of erosion.

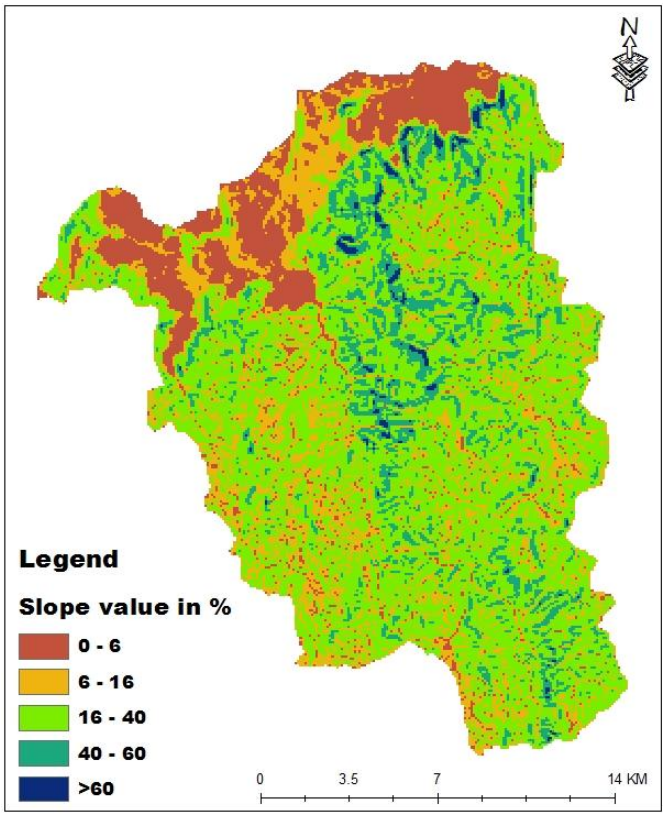

Figure No. 4: Slope map of Sebeya catchment

2.1.6 Climate

- **Rainfall**

The rainfall pattern of Rwanda is bi-modal i.e. it has two distinct rainy seasons. A heavy rainy season (March, April, and May), and a light rains season (September, October, November, and December). Sebeya catchment is characterized by high rainfall (1,200 mm/year and above) and a relatively short dry season in June - August. Erratic showers continue in January – February, which is considered as the second dry season in the country (3). Rainfall distribution in Sebeya catchment as indicated on the rainfall map (figure no.5) varies between 1,076mm to 1,653mm.

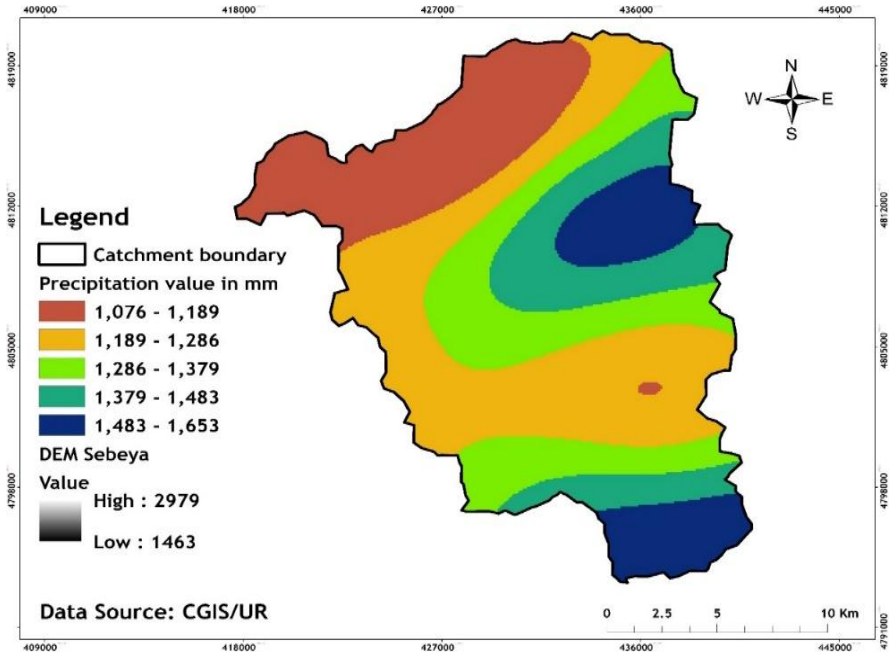

Figure No. 5: Rainfall map of the Sebeya catchment

- **Temperature**

Rwanda has a climate with an average temperature of around 20°C and low monthly variation. Sebeya has various regions with a high elevation greater than 2,000m while the annual average temperature is a bit lower at around 17°C. Rwanda has a dry climate in the East (lower elevation) and a wet climate in the West (high altitude of mountains) resulting in a large and varied pattern of agro-ecological zones. This variation leads to a complicated and uncertain picture for potential changes in Rwanda's overall climate (3).

2.2 Data and methods

2.2.1 Literature review

To have historical background information about the study area in a broad sense, some existing published materials have been read. These include government official documents, different reports of government bodies, and other related journal articles.

2.2.2 Site visits

During the study period, different site visits were conducted to get precise information about the study area: farmers' interviews, taking GPS coordinates of main features and socio-economic activities, land use &land cover observation, monitoring Sebeya river about its sedimentation, its water quality, and its flooding issues.

2.2.3 Survey methods

Informal interviews were addressed to the Sebeya catchment farmers to get information on the catchment knowledge, agricultural practices, and ongoing soil and water conservation projects in the area. It was useful to get a broad understanding of the topography, the land uses, and to pinpoint specific issues of the catchment.

2.2.4 Data analysis Tools

ArcGIS software was used to delineate the catchment and to generate various important maps used in this study. Global Positioning System (GPS) device also helped to locate some catchment features. Microsoft Excel was used to analyze data.

3. LAND USE AND LAND COVER (LULC) INVENTORY

Land use and land cover are not identical terms. Land cover denotes the physical, chemical, or biological categorization of the terrestrial surface (For example, a grassland, forest, or any cover on the land surface such as roads and buildings or any water body), whereas land use refers to purposes associated with that cover such as raising cattle, recreation, housing (residential, commercial, industrial, etc.) or any other type of human activities. Land use is the arrangements of activities by people in a certain land cover type to produce or to change or to maintain it (8).

Land-use and land-cover changes refer to quantitative changes in the aerial extent (increases or decreases) of a given type of land use or land cover, respectively. However, land-cover changes may result either from land conversion (a change from one cover type to another), or land modification (alterations of structure or function without a wholesale change from one type to another), or even maintenance of land in its current condition against agents of change (9).

Sebeya land cover classes including forest plantation, rainfed herbaceous crops, herbaceous vegetation shrubs, tea plantation, water bodies, etc as highlighted on the land cover map (figure no.6). Excessive trees and vegetation retards soil erosion in the catchment.

The major land use classes in Sebeya catchment include cattle grazing, agriculture, and forest plantations. There are practices to support green agriculture and mining, but several cases of unsustainable mining and agriculture still cause terrible sedimentation of the Sebeya river

during heavy rainfall (3). The table4 has been generated from the figure no.7 to show different land use classes in the catchment.

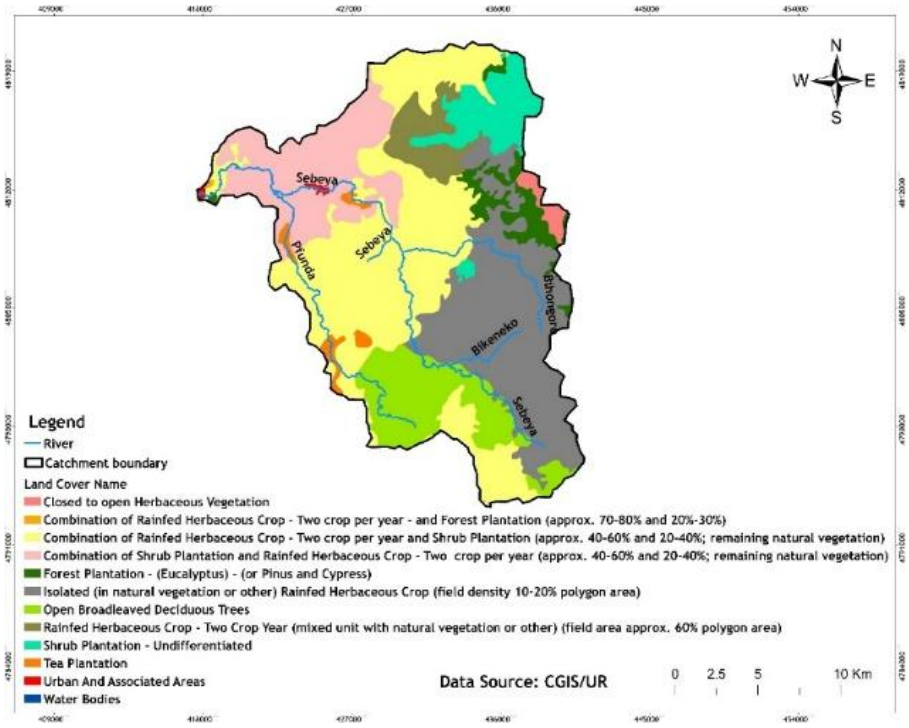

Figure No. 6: Land cover map of Sebeya catchment

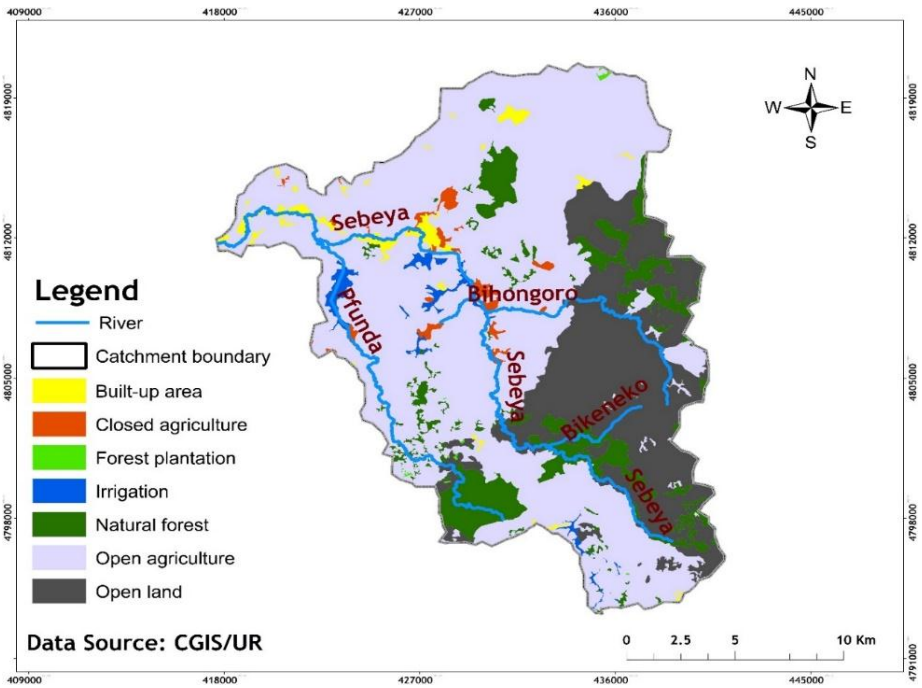

Figure No. 7: Land use map of Sebeya catchment

Table No. 3: Land use classification in Sebeya catchment

S/N	Land-use type	Area covered (km^2)
1	Natural forest	0.297
2	Built-up area	15.372
3	Closed agriculture	5.784
4	Forest plantation	0.654
5	Irrigation	5.556
6	Natural forest	59.165
7	Open agriculture	167.25
8	Total Open land	109.922
Total		**364**

3.1 Surface water

3.1.1 Rivers

Sebeya catchment contains two main rivers, the Sebeya and Pfunda. These rivers are the source of water for the Gihira Water Treatment Plant and hydropower generation of Keya, Gihira, and Gisenyi Hydropower Plants. It is also drained by several small rivers including Bihongoro, Gatare, and Karambo upstream (10).

Sebeya river is running in the North – Westerly direction along 48 km from its source in the mountains of Congo-Nile divide at an altitude of 2660 m.a.s.l to its outfall at Lake Kivu at an altitude of 1470 m.a.s.l (3).

The two main rivers are indicated on the hydrographic map (figure no.8) along with small rivers and tributaries are connected to them.

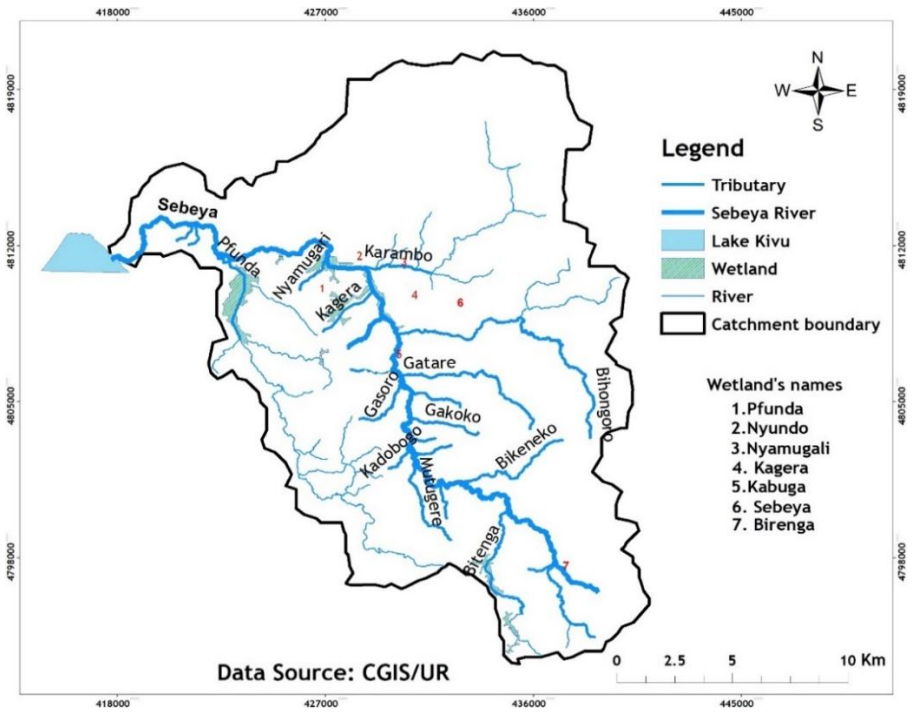

Figure No. 8: Sebeya catchment hydrographic map

3.1.2 Lakes

Except for Lake Kivu that is found at the outlet of Sebeya catchment, no other lake available within the whole catchment as it is shown on the hydrographic map (figure no.8).

3.1.3 Wetlands

Wetlands are characterized by the presence of hydrophytic plants, hydric soils, and wetland hydrologic patterns. They are very essential to the catchment as they deliver wildlife habitat, recharge the groundwater, and provide stormwater retention. The hydrographic map of Sebeya catchment (figure8) shows a series of wetlands associated with rivers found in the catchment. These wetlands include Pfunda, Nyundo, Nyamugali, Kagera, Kabuga, Sebeya, and Birenga.

3.1.4 Terraces

Terracing is one of Sebeya catchment opportunities that are presently available to help in stabilizing soils and enhancing land and water productivity. Land terracing has proved to be the Best Management Practice (BMP) of soil erosion control in some localities of the catchment (4).

3.1.5 Water ponds and open drains

Open drains are some of the soil conservation measures used throughout the catchment. Integrated stormwater management for floods and soil erosion control should be adopted in Sebeya catchment.

3.2 Forests

Forest cover in Sebeya catchment is above the national target of 30% but more than one third is considered degraded, i.e. shows signs of a tree falling or other forms of degradation. This is even the case of Gishwati National Park, which needs proper management to restore healthy forests (3). Farmers in the catchment have a willingness to plant and to expand the surface area of individual forests as there is a high demand for forestry products. For instance, a 4m timber costs 2.18 USD, a 4m wooden plank costs 1.96 USD whereas a bag of charcoal costs about 9.84 USD locally; 10.94 USD at Mahoko center; 13.13 USD in Rubavu town and 16.41 USD in Goma-DRC (4).

3.3 Agriculture farmlands

As observed through the site visits conducted in the catchment, the economy of the area is mainly dominated by agriculture activities including food and industrial crops like tea plantation. Food crops grown in the region are banana plantation, beans, sorghum, maize, vegetables (cabbages, celery, ...), Irish potatoes, soybean, pyrethrum, and groundnut which generate an important income for rural farmers. Forage plants are not given priority. Agriculture is the primary source of livelihood income of farmers in the catchment. Farming is done by both organic and chemical fertilizers.

3.4 Pastures

Pastureland island used that, if managed properly, it offers many environmental benefits. Well-managed pastures have lower soil loss rates than most other crops. Also, they can provide good wildlife habitat and have minimal effects on stream quality. Overgrazing is the most widespread problem associated with pastures and it causes numerous problems such as increases in soil erosion, reduction in the productivity of forage species, greater runoff rates, and decreases in the habitat quality for wildlife. In the Sebeya catchment, livestock is also considered as an economic activity generating income for farmers.

3.5 Biodiversity

The Sebeya catchment is entirely located within Albertine Rift Montane Forests Ecoregion as classified by the World Wildlife Fund for Nature (WWF). Albertine Rift Montane Forests covers the Western part of Rwanda. It is an area of exceptional faunal and moderate floral endemism. These mountains also support the Mountain gorilla, which is one of the most charismatic flagship species in Africa, and an effective target for much of the current conservation investment in the area. Although there is several National Parks and Forest Reserves in the area, their management is difficult over much of the ecoregion due to various threats which include: conversion of most forest areas outside reserves into farmland, together with lodging, firewood collection, and bushmeat hunting within the remaining forest areas.

3.6 Roads and bridges

Apart from the main paved road, other roads are earthen made of varying quality and vulnerable to be damaged by heavy rainfall, floods, and landslides. The paved road network is located in the Northern part of the catchment between Rubavu and Musanze, while the remaining part of the catchment is served by the unpaved road network leading to difficult accessibility of the hinterland (3). The management of these roads is associated with that of bridges. The present connection of roads such as the national paved road, national unpaved road, feeder roads, and District roads are shown on the roads map (figure no. 9).

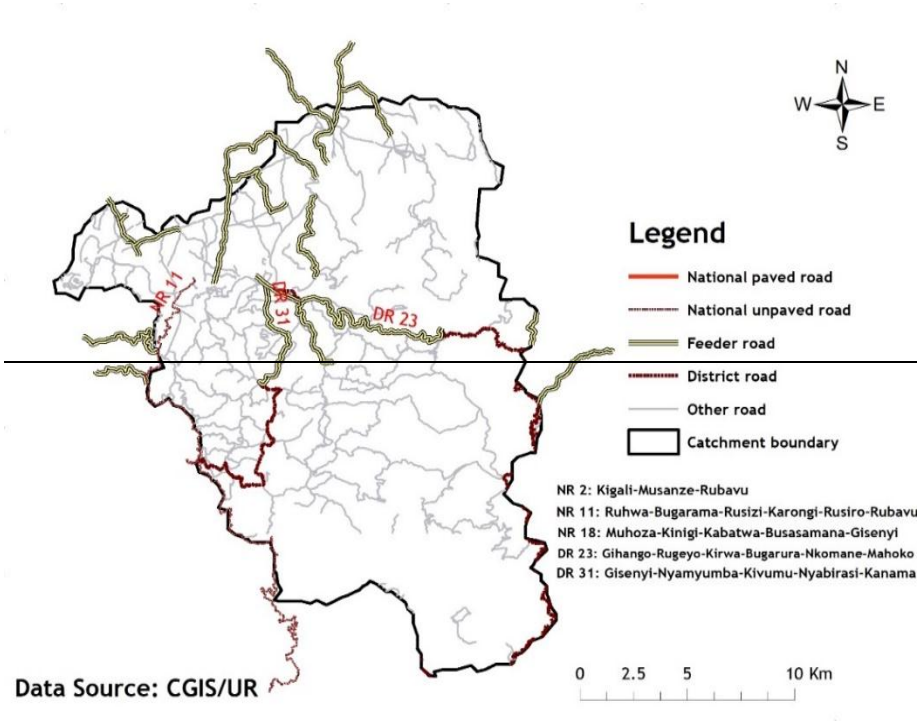

Figure No. 9: Map of roads network in Sebeya catchment

3.7 Resettlement

Settlements, such as Rubavu town, Mahoko Business Center in Kanama sector, and other settlements along the national road Musanze – Rubavu form a very big fraction of the overall land use of the catchment. There is a significant increase of rural grouped settlements (Umudugudu) which facilitates the provision of basic services (WASH, electricity, schooling, healthcare, etc.) (3). However, the built-up area also leads to an increase in impervious surfaces as well as increased runoff.

3.8 Mining

There is some illegal mining along the Sebeya river. In 2012, all mining activity along the river was suspended due to environmental damages. The mining companies were mainly engaged in extracting Wolfram and Coltan. Their activity has polluted the river and in some cases, the river has been diverted. The mining released large volumes of silt into the river, upsetting the natural balance. Mining areas are mostly found in Ngororero and Rutsiro Districts where sand and other composition of sediments generated are transported by runoff towards downstream.

3.9 Effects of land use on water resources

Generally, land-use changes affect water resources in terms of quality. The main sources of pollution of surface water are runoff from mines and erosion from hillside agriculture. Water quality data are scarce. Water quality monitoring in Rwanda has systematically been taken up recently by former RNRA- IWRM department at a limited number of locations throughout the country. Currently, water quality is monitored at the outlet of the river Sebeya flowing into Lake Kivu. Data analyzed from these measurements and findings show that there are very high sediment loads and turbidity due to mining and traditional farming methods. High loads *of E. coli* and coliform bacteria from untreated sewage, high organic loads, and high biological oxygen demands (BOD) and chemical oxygen demands and resulting in low concentrations of oxygen. Recorded turbidity and TSS values were 1102 NTU and 4414.5 mg/L respectively. All turbidity values recorded are above WHO and RSB drinking water standards (5-25 NTU) (3).

4. SOIL EROSION

4.1 Types of soil erosion in Sebeya catchment

Various types of soil erosion which mostly are to happen in the catchment are investigated through informal interviews and visual observations. Most voices indicate erosion types like gully erosion, rill erosion, interracial erosion, and stream bank erosion.

4.2 Causes of soil erosion in Sebeya catchment

During site visits and informal interviews, various causes of soil erosion in the Sebeya catchment have been investigated. The natural causes include the slope of the terrain, rainfall impact, runoff causing sometimes floods, and landslides. Heavy rainfall is the leading natural cause of soil erosion, human activities, and lack of the BMPs being other most severe causes of soil erosion in Sebeya catchment. The effects of earthquakes and wind are negligible.

4.2.1 Rainfall intensity, runoff, and temperature

Both rainfall and temperature affect soil erosion. There is a direct relationship between the amount of rainfall and soil erosion. Rainfall intensity influences both the rate and volume of runoff and then the scale of soil erosion. Temperature affects the climatic type, which

governs the types of crop grown and the amount of ground cover that exists. Temperature is important in producing the desired level of ground cover to protect soil from erosion.

In highlands, maintenance of the desired level of ground cover is difficult because of low temperatures and the short growing season of plants. Similarly, in arid regions, the warm temperature can result in more rapid decomposition of organic matter. For these 2 extreme events of temperature, the soil becomes more susceptible to erosion during intense rains.

4.2.2 Soil properties

Soil texture, organic matter content, macroporosity, and water infiltration are the major properties that influence soil erosion. Antecedent water content is also an important factor as it defines the soil pore space available for rainwater absorption. Soil aggregation affects the rate of detachment and transportability. Large and unstable aggregates are more detachable while clay particles are transported more easily than sand particles, but clay particles form stronger and more stable aggregates. Besides, organic materials stabilize soil structure and coagulate soil colloids. Compaction reduces soil macroporosity and water infiltration and increases runoff rates. Interactive processes among soil properties define soil erodibility (11).

4.2.3 Slope gradient and length

Slope steepness is one of the important factors in soil erosion. The greater the slope, the more is the erosion. Slope steepness influences soil erosion in several ways. The increased velocity of runoff water in steep slopes allows more soil to be detached and transported. Surface detention of water is low and breaking of raindrop energy cannot form in steep slopes. Therefore, steep slopes are susceptible to erosion. The slope length is also an important factor affecting soil erosion. If the slope is longer, a large quantity of rain will fall on it and if the rate of rainfall exceeds the rate of infiltration, there will be a large accumulation of water at the base. Therefore, the longer the slope length more is the more erosion.

4.3 Factors affecting soil erosion in Sebeya catchment

4.3.1 Rainfall

Rainfall initiates the process of erosion by provoking soil detachment and transport directly by raindrop splash or through the contribution of rain to runoff. There is a direct relationship between the amount of rainfall and erosion. Rainfall intensity influences both the rate and volume of runoff and then the scale of erosion (12).

4.3.2 Soil

The likelihood that the detachment and entanglement of soil particles occur depends not only on rainfall characteristics but also on the structural characteristics of the soil. Soil erodibility is defined by (13) as the resistance of soil to both detachment and transport. It is dependent on parameters such as soil texture, aggregate stability, shear strength, and infiltration capacity (14).

4.3.3 Topography

Mountainous regions are more prone to soil erosion. A higher slope gradient creates a higher flow velocity which causes more detachment and transport of soil particles (15). In general, soil loss increases exponentially with slope steepness for tropical soils (16).

4.3.4 Vegetation

Vegetation plays important role in protecting soil against water erosion. Vegetation intercepts raindrop and reduces the kinetic energy of water that reaches the soil, causing a lower detachment of soil particles (17). Vegetation also improves the soil structures by adding organic matter into the soil. With high organic matter content, the soil will have more pores which in turn helps to increase the infiltration and water holding capacity of the soil. Also, the humus layer itself acts as a sponge that absorbs moisture and allows it to enter the soil. That is why soils having low organic matter and humus layer are susceptible to erosion because of increased runoff. In the vegetative areas, the root network, the channels of root decay, and animal burrows tend to spread out the runoff laterally and thus dissipate its energy. Further, the root system below the soil surface binds and aggregates the soil through the mechanical actions which prevent the soil from erosion and landslide. By penetrating the soil mass, roots reinforce the soil and increase soil shear strength (18).

4.3.5 Management

Even in ancient times, farmers discovered that shaping lands in certain ways such as contour planting and terracing was necessary for sustained agricultural production (16). Management techniques can work in two ways: human enforced mismanagement is a major cause of erosion (19) while soil erosion control measures implemented can take various forms and have variable effectiveness (2).

4.3.6 Human activities

Human activities cause accelerated soil erosion. Human activities are many and unavoidable. They are human life activities. Disturbance of existing drainage flow, removal of native vegetation, construction of improperly designed erosion control facilities, construction of impermeable surfaces, disturbance of land slopes, disturbance of highly erosive soil and road construction, farming, grazing, logging, and mining are typical human activities causing soil erosion. A combination of two or more elements will increase significantly soil erosion.

5. SOCIAL ECONOMIC ISSUES

The economy of Sebeya catchment relies strongly on rain-fed agriculture, both for rural livelihoods and exports of tea and coffee. About 90% of the country's population is engaged in agricultural activities. Horticulture is common in all four Districts in the catchment as the fertile soils in the area lead to high production levels of vegetables and Irish potato. Both commercial and artisanal mining is common. Sand-mining in riverbeds is also an important economic activity in the downstream sections of the Sebeya river. Sand-mining has the dual benefit of producing a high-quality construction material, that is much in demand, as an economic benefit, and helps maintain the flow capacity of the river. The complicating factor is that the mined sand derives from upstream mining activities and soil erosion. The economic issue of sand-mining activities is conflicted with large adverse impacts on the catchment and usability of the Sebeya river for water supply and hydropower. This is a complex issue that the Sebeya catchment plan tries to address (3).

About other economic activities, the Gishwati forest has been largely converted to livestock grazing land, Nyabihu District being the largest producer of milk in Rwanda. Although it is not technically speaking to be within Sebeya catchment boundaries, Lake Kivu fishery may be viewed as economic development of this catchment because Lake Kivu finds its replenishment from the Sebeya river. Some parts of the original Gishwati - Mukura forests were established as National Park in 2016 and this will help in terms of maintaining biodiversity and nature conservation (including many interesting bird species), as well as in increasing tourism revenues. Sebeya is one of the national potential tourist sites due to its proximity to Lake Kivu and the Volcanoes National Park (3).

6. NATURAL HAZARDS

6.1 Floods and landslides in Sebeya Catchment

Like other East African region's countries, Rwanda is subjected to periodic high floods. Two types of floods that happened in Rwanda include flash floods and river floods (21). In Sebeya catchment, flooding typically occurs in flat areas around Nyundo which acts as a natural retention buffer for floods. Sebeya is a small-scale catchment (~364 km^2) with a fast rainfall-runoff reaction so that floods in this catchment are known to be flash floods type. The population testifies that flooding after heavy rainstorms occurs within a period of 20 minutes to 3 hours (10).

Floods in Sebeya catchment happened frequently in Rubavu District. The flood was observed on 16 May 2010 in Northwestern at Rubavu District, Nyundo Sector where 7 people lost their life, 100 residential houses were destroyed, 87 ha of crops destroyed and many people displaced because of a heavy flood. In September 2008, the heavy rains and winds adversely affected 8 among 12 sectors of Rubavu District: Gisenyi, Rubavu, Nyamyumba, Nyundo, Cyanzarwe, Nyakiriba, and Kanama. Also, Rutsiro experienced floods in 2015 where one person died and this was confirmed by the Sector Executive Secretary as read in Kigali Today newspaper. Recently on 3rd march 2018, Rubavu District located in the Western province also experienced floods and 5000 households were affected. Landslides risk in four Districts covering the catchment is ranging from moderate to high (3).

6.2 Droughts in Sebeya Catchment

The Global Facility for Disaster Reduction and Recovery (GFDRR) (accessed at https://www.gfdrr.org/rwanda) maintains a risk atlas with vulnerability maps to hazards for Rwanda. Sebeya catchment covers 4 Districts, each vulnerable to hazards at different degrees. Among the Districts of the catchment, (Nyabihu, Rubavu, Rutsiro) Districts are not vulnerable to drought while Ngororero District shows a certain vulnerability.

Recently a 30-year historical dataset for Rwanda was completed, using a combination of station and satellite data (Rwanda Meteo Maproom), allowing some insight into expected climate change effects. It shows that the climate is already changing, with temperatures increasing about 0.35°C per decade since the 1980s, which is higher than the global average (3).

6.3 Earthquakes

Sebeya catchment region is closer to the Birunga volcanoes zone where some of them are still active. These are Nyamuragira and Nyiragongo located in the Democratic Republic of Congo (DRC). Regular eruptions of these volcanoes, essentially Nyamuragira, are the origin of many earthquakes in the region. In 2002, with the Nyiragongo eruption, close to Mahoko and Rugerero villages, it was observed many cracks on some houses built without a lintel. There was no complete house destruction. This earthquake was of 7 magnitudes(10).

7. CONCLUSION AND RECOMMENDATIONS

This work delivered some important information on different aspects of the Sebeya catchment which can help in various projects of soil erosion control. Informative maps like land cover and land use maps, soil map, hydrographic map, slope map, topographic map, etc were produced and the situation of Sebeya catchment in terms of water quality, natural hazards risk, socio-economic issues are pinpointed throughout this research. High rainfall, steep slopes, and high soil erodibility are the main natural causes of soil erosion in the Sebeya catchment. Human activities (Improper agricultural practices, illegal mining, etc.) are blameable to accelerate soil erosion rates in this catchment. Soil and water conservation measures should be established for the sustainable management of the catchment.

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